MINERAL RESOURCE EVALUATION OF LANDS SELECTED FOR THE UTAH TEST AND TRAINING RANGE EXCHANGE

Prepared for the Utah School and Institutional Trust Lands Administration

(Photo: Newfoundland Mountains viewed from the Hogup Mountains)

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Spreadsheet and geodatabase with all tract evaluations are included on accompanying compact disc.

EXECUTIVE SUMMARY

The Utah Geological Survey evaluated mineral potential of 356 tracts administered by the Utah School and Institutional Trust Lands Administration and the U.S. Bureau of Land Management that have been nominated to be part of the Utah Test and Training Range land exchange, and found potential on many of those tracts. Several mineral commodities (clay, crushed stone, gypsum, high-calcium limestone, high-magnesium dolomite, potash and other salts, sand and gravel, silica, and metals) have occurrence potential and some of those commodities have potential to be developed in the future. Table ES-1 summarizes our findings from evaluating the tracts. The mineral commodities having the greatest significance are high-calcium limestone and high-magnesium dolomite. We identified 26 tracts that have high occurrence potential and 15 tracts that have moderate occurrence potential for high-calcium limestone. Development potential is high or moderate on 19 of those tracts. High-magnesium dolomite occurrence potential is high on 10 tracts and moderate on 16 tracts, 7 of which have high or moderate development potential. The development potential of these commodities is primarily linked to Graymont's active lime operation in the Cricket Mountains. Many tracts also have sand and gravel or crushed stone occurrence potential, but sand and gravel development potential is more significant than crushed stone. Small amounts of gypsum are being produced in the east part of the West Desert; 20 tracts have high or moderate occurrence potential and 7 of those tracts have high or moderate development potential. Nineteen of the exchange tracts were ranked as having moderate to high occurrence potential for metals, but just four of these were given moderate to high development potential. Although occurrence potential for clay, potash and other salts, and silica exists, development potential for these commodities is considered low.

INTRODUCTION

Background

In February 2017, the Utah Geological Survey (UGS) was tasked by Thomas Faddies, Assistant Director of Minerals of the Utah School and Institutional Trust Lands Administration (SITLA), to evaluate the mineral resource potential of U.S. Bureau of Land Management (BLM) lands involved in the Utah Test and Training Range (UTTR) land exchange. The UGS was also tasked with updating evaluations of SITLA lands prepared by Rupke and others (2014). Nearly 96,000 acres of BLM lands and 84,000 acres of SITLA lands have been nominated for exchange, and the mineral resource potential of those lands is covered by this report.

Table ES-1. *Total number of tracts in Utah Test and Training Range exchange having high or moderate occurrence potential and high or moderate development potential.*

Commodity	High Occurrence Potential	Moderate Occurrence Potential	High Development Potential	Moderate Development Potential
Clay	-	3	-	-
Crushed Stone	41	46	-	2
Gypsum	13	7	2	5
High-Calcium Limestone	26	15	5	14
High-Magnesium Dolomite	10	16	6	1
Potash and Other Salts	2	21	-	-
Sand and Gravel	13	104	1	17
Silica	5	9	-	-
Metals	2	17	1	3

The BLM lands nominated for exchange include 213 tracts totaling about 150 square miles and SITLA lands nominated for exchange include 143 tracts totaling 132 square miles (plate 1). The majority of the BLM and SITLA tracts include both surface and mineral rights; however, a small percentage of the acreage is minerals only. The UGS Energy and Minerals Program has investigated and ranked the potential for minerals on each individual BLM and SITLA parcel. The primary purpose of this report is to provide mineral resource data to facilitate the appraisal of these tracts.

Methods

The UGS used a variety of tools to rank the mineral occurrence potential of the BLM and SITLA tracts including published and unpublished literature, geologic maps, the Utah Mineral Occurrence System (UMOS; http://geology.utah.gov/resources/data-databases/utah-mineral-occurrence-system/), and the U.S. Geological Survey's National Geochemical Database (NGDB). The UGS's unpublished Utah geochemical database; Utah Division of Oil, Gas and Mining's (DOGM) mineral permit database; and SITLA's active mineral lease database were also used to help assess the potential of the tracts. Where no detailed geological mapping was available, we relied on Hintze and others' (2000) 1:500,000-scale map and the older, but more detailed, Stokes' (1963) 1:250,000-scale map. We also were able to use Google™ and NAIP high-resolution orthophotography to zoom in and view the tracts in reasonable detail using ArcGIS. Additional details are provided in the individual commodity sections.

The UGS used a simple classification system to rank the mineral potential of the individual parcels based on (1) the level of certainty of the data and (2) the indicated mineral occurrence potential (appendix A). This classification was applied in similar forms for each mineral commodity from potash to metals, and ranking details are provided for each commodity in their respective sections. We also estimated the development potential of tracts that have some occurrence potential and that classification system is also described in appendix A. The result is a large Excel table and an associated ArcGIS geodatabase that show the evaluation of all of the selected commodities for each tract. The spreadsheet and geodatabase are the main products of this evaluation and are attached. In the spreadsheet and geodatabase, parcels with insufficient data to recognize mineral potential (ND ranking) are denoted simply by an "x" to aid table readability. Summary descriptions of the most favorable mineral resources in the exchange parcels are included in the text.

GEOLOGIC SETTING

The eastern Great Basin has been tectonically active throughout a significant part of geologic time and has major tectonic features including the northerly trending Wasatch line, Cordilleran fold and thrust belt, and Basin and Range extensional terrane (Presnell, 1997). The eastern Great Basin is primarily underlain by Proterozoic rocks on the southwestern margin of the Archean Wyoming Province. The exact southwestern boundary of the Wyoming Province is still poorly defined, but researchers have extended the province boundary westward considering Archean ages of metamorphic rocks in the northwestern Raft River and adjoining Grouse Creek Mountains. The Proterozoic rocks are generally Paleoproterozoic gneisses and schists that were accreted onto the southern margin of the Wyoming Province (Hintze and Kowallis, 2009). These older rocks are overlain by weakly metamorphosed Neoproterozoic quartzite, tillite, and shales.

The early Paleozoic was a time of passive -margin sedimentation in the eastern Great Basin. The Wasatch line marks the approximate break in slope between continental sedimentation to the east, and thicker, marine, miogeoclinal sedimentation to the west. In Cambrian time alone, for example, eastern Utah received roughly 600 m of sedimentary strata while western Utah typically accumulated over 3000 m (Stokes, 1988; Hintze and Kowallis, 2009).

During the Mesozoic, a series of orogenies affected the eastern Great Basin. The Jurassic Nevadan and Elko (Thorman and others, 1991) and the Cretaceous Sevier (Armstrong, 1968) orogenies disrupted the Paleozoic sedimentary strata. The Nevadan and Elko orogenies resulted in minor deformation and metamorphism, as well as a series of isolated intrusions in westernmost Utah (Presnell and Parry, 1995). The effects of the Sevier orogeny are more widespread, resulting in extensive thrust faulting and associated northerly trending folds in most of western Utah. However, the eastern Great Basin, unlike the western and central Great Basin, only has few Jurassic intrusives and no recognized Cretaceous stocks. The Laramide orogeny in the Late Cretaceous generated a series of uplifts and sedimentary basins in eastern Utah, but had fewer recorded effects in the west.

These Mesozoic compressional and magmatic orogenies resulted in a significantly thickened and heated crust in the Great Basin that persisted into the Tertiary (Best and others, 2009). Erosion of these Sevier highlands in the west, and Laramide uplifts in the east, sent detritus into the Paleocene-Eocene basins of eastern and southern Utah (Hintze and Kowallis, 2009).

During the Tertiary, magmatism in the eastern Great Basin evolved from (1) mid-Eocene to early Oligocene calc-alkaline, intermediate to felsic, subduction-related magmas, to (2) late Oligocene to early Miocene and (3) mid-Miocene to Quaternary, bimodal, extension-related magmas. The Eocene and early Oligocene (about 40 to 29 Ma) magmatic suites range in composition from andesite to dacite to low-silica rhyolite, and this magmatism produced several calderas in west-central and southwestern Utah. The late Oligocene to early Miocene (about 26 to 17 Ma) bimodal suite is predominantly andesite and rhyolite accompanied by extension and a few calderas in southwestern Utah. The final mid-Miocene to Quaternary (about 16 Ma to present) suite is strongly bimodal, basalt and rhyolite associated with significant extension (Krahulec, 2015). This late Oligocene to present extension results in both today's distinctive basin and range topography and the internal drainage of the Great Basin.

INDUSTRIAL MINERALS

Several industrial minerals were evaluated for this report including clay, crushed stone, gypsum, high-calcium limestone, high-magnesium dolomite, potash and other related salts, sand and gravel, and silica. Descriptions of these mineral resources are listed below in alphabetical order. The evaluated industrial minerals were selected for having at least some occurrence potential on tracts within the UTTR exchange area and some basis for evaluation, including enough data for us to make a reasonable determination. For instance, gypsum has been produced in the area of the UTTR and available data exist showing the extent and quality of deposits, allowing us to provide a reasonable assessment.

For each mineral resource we include a basic criteria for how we evaluated occurrence potential; however, based on the individual characteristics of a tract, our final evaluation may diverge slightly from the general criteria. Also, because sufficient volume and tonnage is required for many industrial mineral deposits to be viable, we sometimes lowered the occurrence potential ranking if available data suggested insignificant amounts.

Clay

Geologically, clay deposits fall primarily into two broad categories: (1) deposits resulting from hydrothermal alteration (hypogenic) and (2) deposits formed by surficial processes (epigenic) that commonly occur in shale and mudstone (Van Sant, 1964). For industrial purposes, clays can be described as very fine grained, naturally occurring, earthy, argillaceous material and are typically not categorized by their mineralogical composition (Grim, 1953). Clay is generally classified, marketed, and priced based on its industrial use. Several small clay operations that produce bentonite, common clay, and high-alumina clay are found throughout Utah. Uses for these clays include well drilling applications, brick making, and use in Portland cement production (Boden and others, 2016). No clay operations are located in the vicinity of the UTTR exchange tracts.

Clay occurrence potential on UTTR tracts is primarily in Paleozoic shale-bearing formations. These geologic units would probably be most suited for common clay production, but further evaluation could reveal other potential uses. Broadly speaking, occurrence potential for clay in the UTTR is low (plate 2), but we assigned a moderate occurrence potential to two small tracts in the Oquirrh Mountains due to the presence of the Long Trail Shale Member of the Great Blue Limestone, which had some production in the past in other locations (figure 1). We assigned a low occurrence potential to tracts where unit descriptions indicate presence of mudstone or shale, but little or no clay was produced from the same unit(s) in other locations. One UMOS record for a UTTR

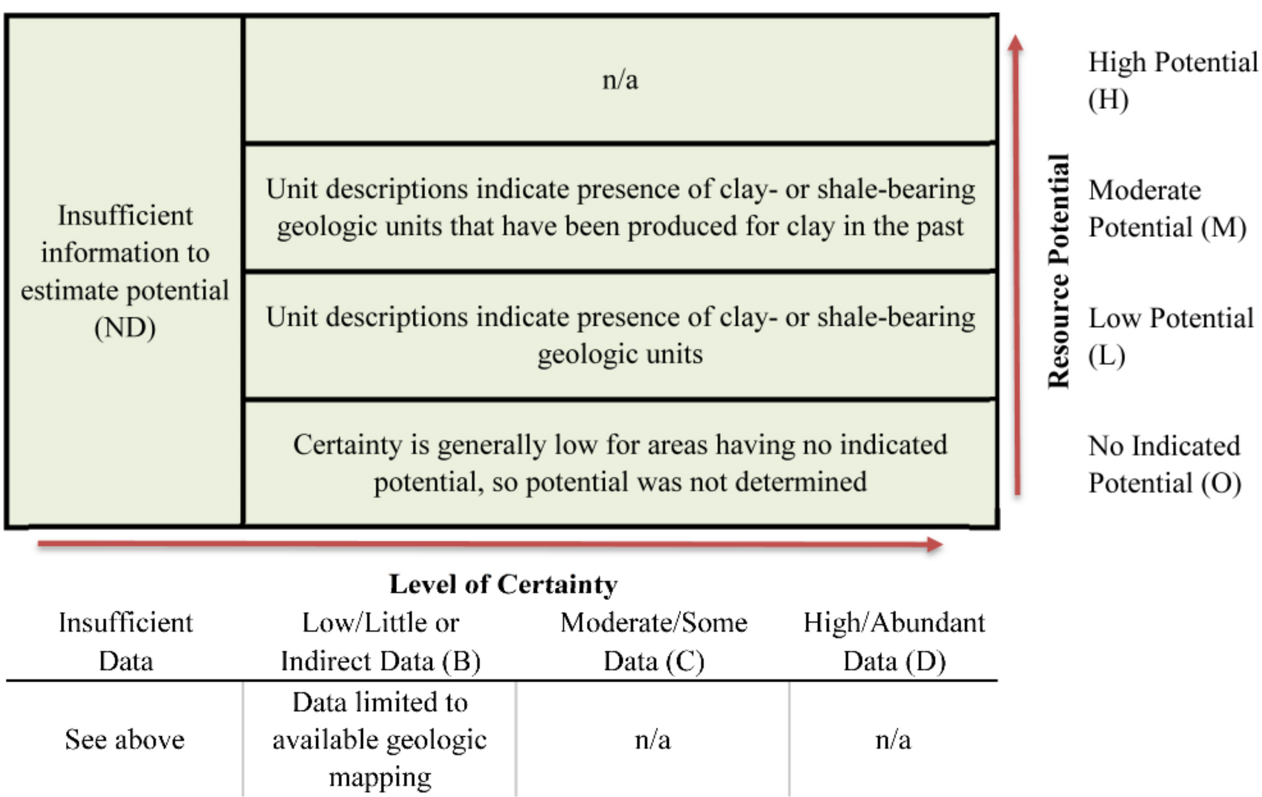


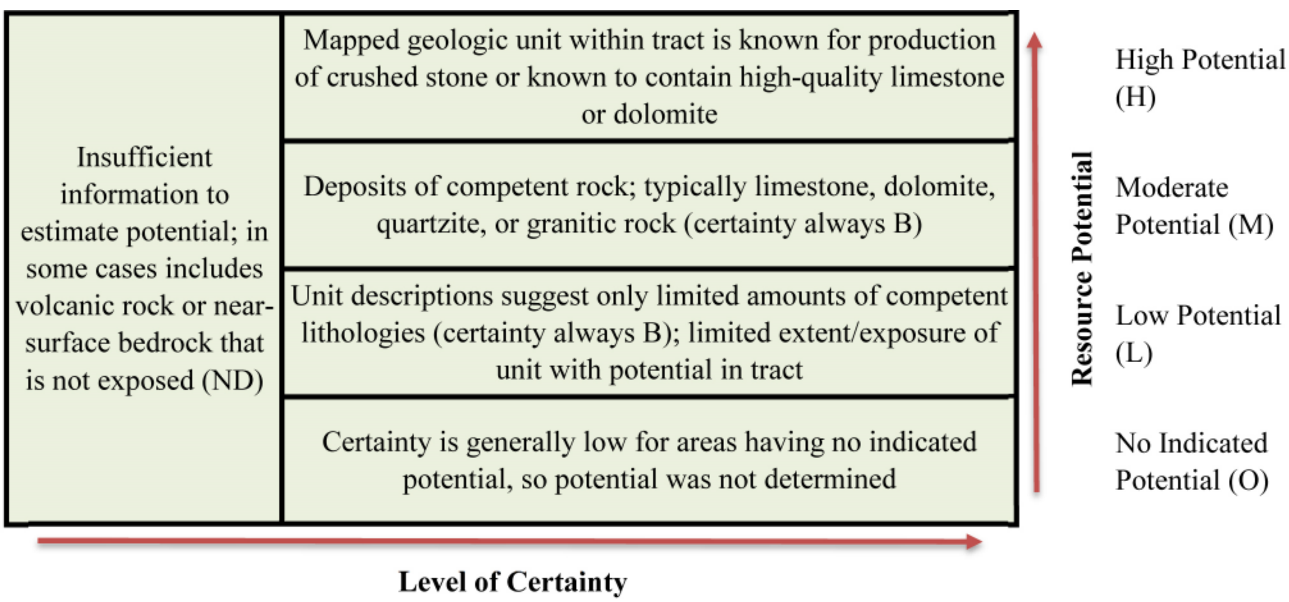
Figure 1. *Clay occurrence potential ranking system.*

tract in the Drum Mountains shows a small halloysite occurrence, and we assigned a moderate occurrence potential to this tract. For a brief time a small mine permit was opened for halloysite, but the permit did not result in production. Development potential of clay deposits in the UTTR is low.

Crushed Stone

Crushed stone is commonly used for construction aggregate (Willett, 2017) and is typically extracted from geologic units containing rocks with high compressive strength. Rock types suitable for crushed stone often include limestone, dolomite, granite, and traprock (often basalt). In the U.S. in 2016, most crushed stone (70%) was sourced from carbonate rocks (limestone and dolomite) (Willett, 2017). Because crushed stone is a low unit-value commodity, it is generally only surface mined at low stripping ratios. Willett (2017) estimated that the average cost of a ton of crushed stone in 2016 was about $9.98. The particular attributes of crushed stone mined in a given area are affected by the overall availability of crushed stone and types of local end uses.

Occurrence potential for crushed stone exists on several of the evaluated tracts (plate 3), and the criteria for evaluation are shown in figure 2. Several geologic units exposed in the tracts include competent lithologies and some have been extracted in the past for crushed stone. Geologic formations in tracts in the UTTR that have previously been used for crushed stone include the Mississippian Great Blue Limestone, the Pennsylvanian Bingham Mine Formation of the Oquirrh Group, and some trachyandesite in the



Insufficient Data	Low/Little or Indirect Data (B)	Moderate/Some Data (C)	High/Abundant Data (D)
See above	Data limited to available geologic mapping	Past extraction for crushed stone adjacent to tract	n/a

Note: If extent of a unit with potential is limited within a tract, potential ranking was commonly reduced.

Figure 2 *. Crushed stone occurrence potential ranking system.*

Grayback Hills. Other units that have high potential based on past use for lime or dolomitic lime production include Cambrian Dome Limestone, Cambrian Limestone of Cricket Mountains, Ordovician Fish Haven Dolomite, Silurian Laketown Dolomite, and Devonian Guilmette Formation. Because rock used for lime or dolomitic lime production must often meet certain physical standards, this rock would almost certainly qualify for use as crushed stone for construction purposes as well.

Potential beyond these units generally exists in other Paleozoic carbonates and quartzites, which are common in several tracts. We generally assigned tracts that have significant exposures of these units a moderate occurrence potential. If bedrock unit descriptions suggested lithologies with lesser potential or if units with potential were limited in extent on a given tract, we adjusted potential accordingly. Insufficient data exist to assign an occurrence potential for crushed stone to several tracts in the UTTR exchange.

Due to remoteness of most of the tracts involved in the UTTR exchange, development potential is generally low. However, we did assign moderate potential to two tracts in the vicinity of past crushed stone operations.

Gypsum

In the U.S., gypsum is primarily used to produce wallboard and plaster products, but it is also used in cement production, for agricultural purposes, and other applications (Crangle, 2017). Occurrence potential for gypsum in the UTTR exchange area exists in gypsiferous dune deposits. Gypsiferous dunes form as crystals precipitating at or near the surface of the Great Salt Lake Desert are transported by wind and accumulate primarily on the east side of the desert (Eardley, 1962). Dean (1976, 1978) and Stokes (1963) provided low-detail maps that delineated gypsum dunes for the entire Great Salt Lake Desert. Boden (2010) performed a more detailed study of gypsiferous dunes on SITLA sections in the central part of the Great Salt Lake Desert, which included detailed mapping, sampling, and tonnage estimates for gypsum dunes in the area. Solomon (1993) and Doelling and others (1994) also mapped some of the gypsum dunes in detail on 1:24,000 scale geologic maps. The gypsum dunes are not as pure as other gypsum deposits in Utah (Boden, 2010), but ease of extraction has made the dunes a good source of gypsum for soil amendment applications. Currently, gypsum from the dunes is being produced north of Interstate 80.

Figure 3 shows our criteria for ranking gypsum occurrence potential, and plate 4 shows that most of the potential lies on the east side of the Great Salt Lake Desert a few miles north and south of Interstate 80. Generally, we assigned a high potential to tracts where detailed mapping from Boden (2010) indicates the presence of gypsiferous dunes and a minimum estimated resource of about 200,000 tons. We assigned a moderate potential to tracts where Boden's (2010) tonnage estimate shows a minimum of 40,000 tons of gypsum. Boden's (2010) mapping covered most of the relevant areas; however, we used Dean's (1978) and Stokes' (1963) less detailed mapping to assign potential to a few tracts that have some minimal dune potential. Certainty of occurrence potential was considered low unless sample data from Boden (2010) was available for the tract. In one instance, we assigned a high certainty and high development potential due to recent gypsum extraction in the tract. We assigned high development potential to one other highly accessible tract that has an active lease and moderate development potential to a few tracts that are leased for gypsum or have mapped dunes that are relatively accessible.

		Resource Potential
Insufficient information to estimate potential (ND)	Detailed mapping from Boden (2010) indicates presence of gypsum dunes in tract having a minimum estimated resource of 200,000 tons	High Potential (H)
	Boden (2010) indicates a minimum gypsum dune resource of approximately 40,000 tons	Moderate Potential (M)
	Possibility of gypsiferous dunes (certainty always B) or limited mapped extent of dunes in tract	Low Potential (L)
	Certainty is generally low for areas having no indicated potential, so potential was not determined	No Indicated Potential (O)

Level of Certainty

Insufficient Data	Low/Little or Indirect Data (B)	Moderate/Some Data (C)	High/Abundant Data (D)
See above	Data limited to available mapping	Sampling data from Boden (2010)	Past extraction within tract

Note: Although Boden (2010) assigned tonnages to many tracts, we did not consider the tonnage estimates to increase certainty unless sampling or extraction accompanied the estimates to confirm gypsum content.

Figure 3. *Gypsum occurrence potential ranking system.*

High-Calcium Limestone

High-calcium limestone usually refers to limestone that has a 95% or higher $CaCO_3$ content, and it is used in a variety of applications. In Utah, high-calcium limestone is used primarily for lime and cement production, but it is also used for flue-gas desulfurization and as rock dust in the coal mining industry (Boden and others, 2016). Within the UTTR exchange area, most of the high-calcium limestone potential is in Cambrian Dome Limestone, Devonian Guilmette Formation, and Mississippian Great Blue Limestone. The Dome Limestone is currently being mined by Graymont in the Cricket Mountains for lime production (Tripp, 2005; Boden and others, 2016). Tripp (2005) provided data showing that the Guilmette contains high-calcium limestone, and the Guilmette is currently being mined, also by Graymont, for high-calcium limestone in northeastern Nevada, not far from the Utah border. Tripp (2005) also reported on several mines that, in the past, extracted Great Blue Limestone in Utah for high-calcium limestone.

Figure 4 shows our criteria for ranking high-calcium limestone occurrence potential, and plate 5 shows where the potential occurs. We generally assigned a high occurrence potential to tracts that have mapped exposures of Dome Limestone, Guilmette Formation, and Great Blue Limestone. Because a valuable deposit would require sufficient tonnage, areas having limited or isolated exposures of units with potential were commonly downgraded. Based on some analytical data from U.S. Steel (1950, 1957) and Tripp (2005), we assigned a moderate occurrence potential to some exposures of the Wah Wah Summit Formation. We assigned a low occurrence potential to tracts that have other geologic units that include limestone in

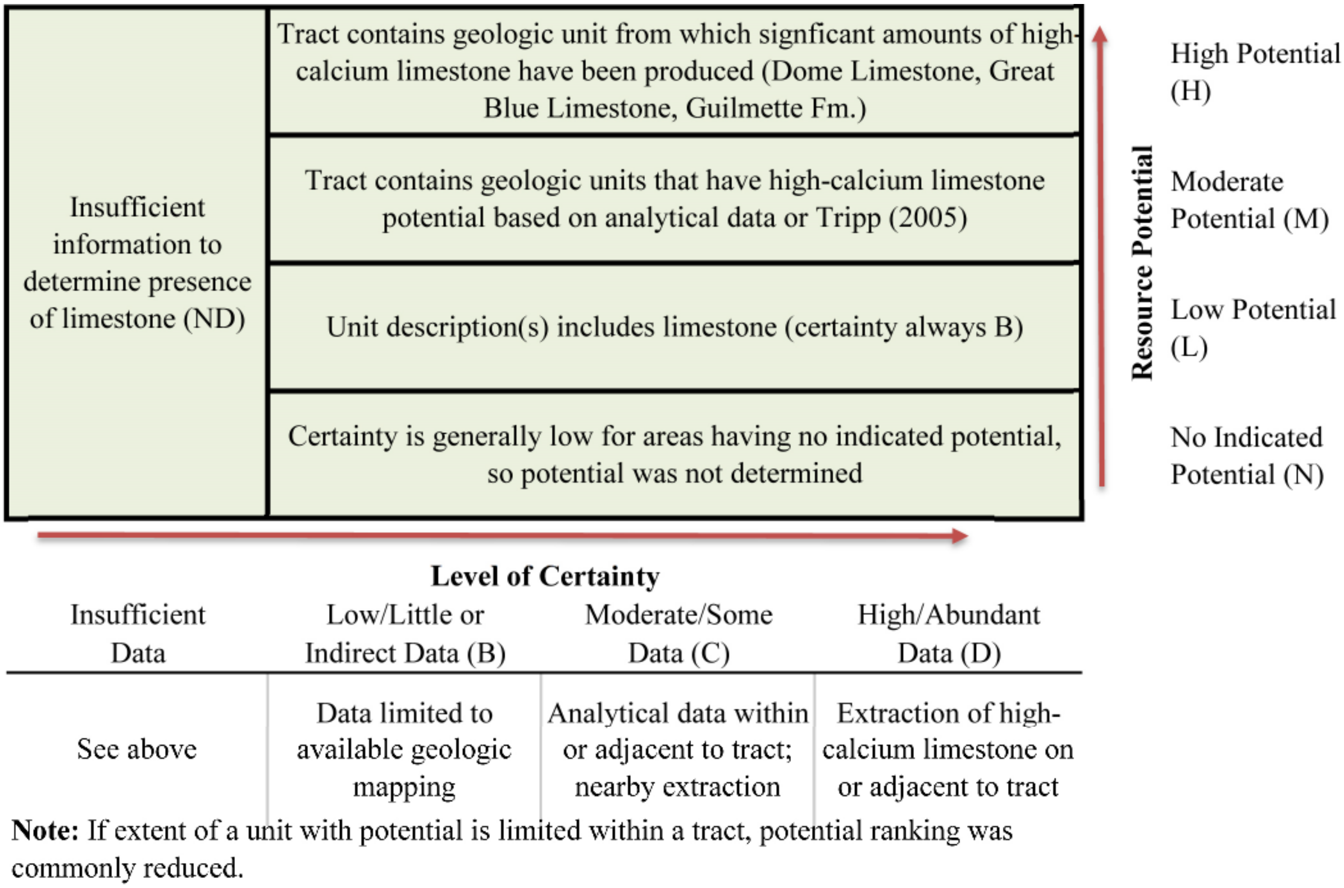


Figure 4 *. High-calcium limestone occurrence potential ranking system.*

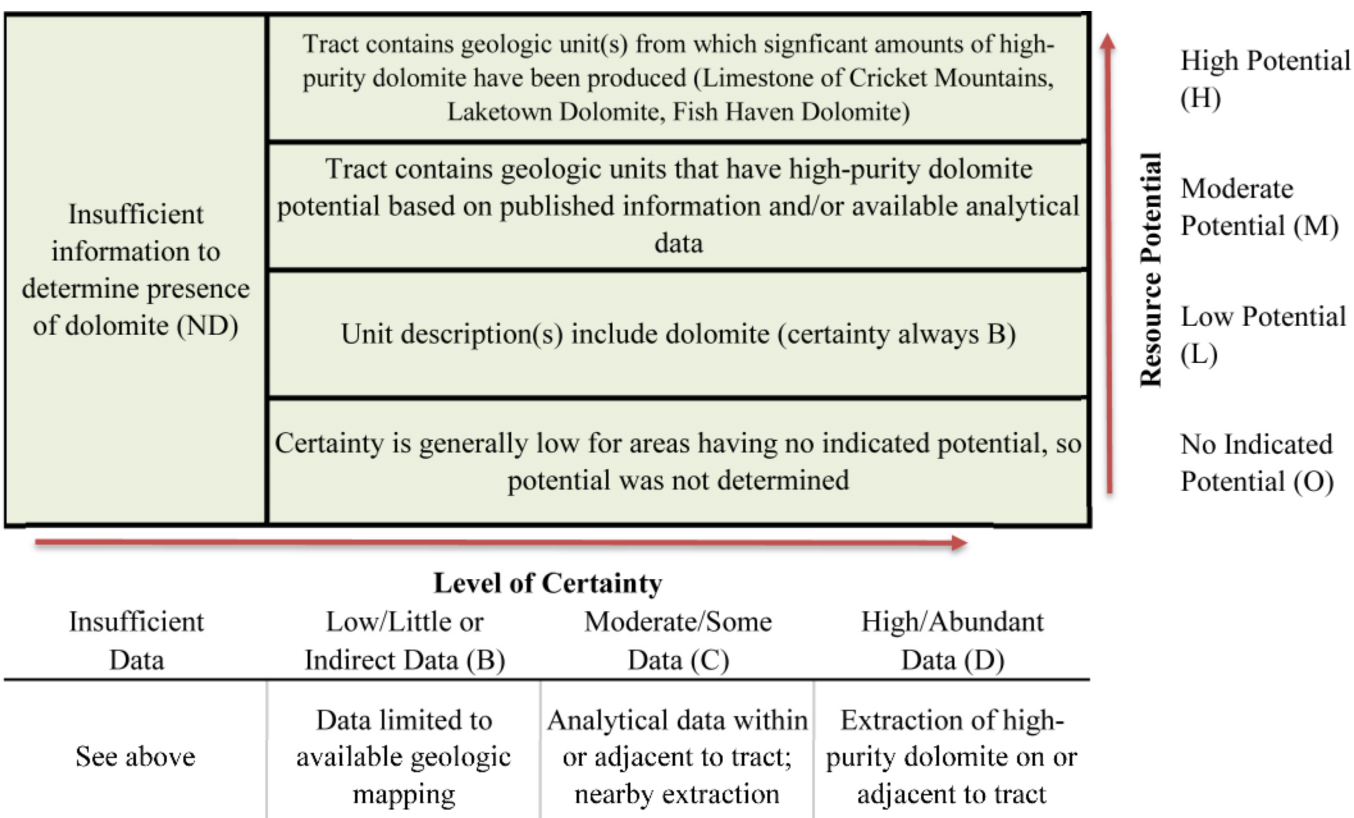
their lithologic descriptions, but are not necessarily known to contain high-calcium limestone. Because analytical data are limited, the certainty of high-calcium limestone occurrence potential is low for most areas. We assigned a higher certainty for a few tracts based on proximity to prior extraction or analytical data.

Development potential of high-calcium limestone in most areas is low with the exception of areas that are in the vicinity of active or recently active mines. The tracts with the highest development potential are in the vicinity of Graymont's operation in the Cricket Mountains and include exposures of Dome Limestone. On the south end of the Lake Mountains is another tract that has some development potential. Great Blue Limestone crops out in this tract and is adjacent to a mine owned by LafargeHolcim in the same geologic unit. The mine is not recently active, but retains a permit and has had extraction of limestone for cement production in the past.

High-Magnesium Dolomite

High-magnesium dolomite generally refers to dolomite with 42% or higher $MgCO_3$ content, and it is used in a variety of applications ranging from construction aggregate to agricultural, chemical, and metallurgical applications. In Utah, the primary use for high-magnesium dolomite is the production of dolomitic lime. Occurrence potential for high-magnesium dolomite in the UTTR exchange area resides primarily in Cambrian, Ordovician, and Silurian dolomites. Currently, dolomite within the Cambrian Limestone of Cricket Mountains, as mapped by Hintze and others (2003), is mined by Graymont for dolomitic lime production. The Ordovician Fish Haven Dolomite and the Silurian Laketown Dolomite were mined for dolomitic lime at the Lakeside Mountains and the north end of the Stansbury Mountains (Morris, 1964; Boden and others, 2016). Williams (1958) and Tripp and others (2006) presented analytical data showing the purity of the Fish Haven and Laketown Dolomites in various parts of Utah, and the National Geochemical Database provides analytical results of Laketown and Fish Haven Dolomites, including from the Newfoundland Mountains, showing high-magnesium dolomite. Morris (1964) also suggested that the Devonian Simonson Dolomite, Sevy Dolomite, and Guilmette Formation are potential candidates for pure dolomite. Unpublished U.S. Steel (1950, 1957) reports indicate that the Wah Wah Summit Formation also contains high-magnesium dolomite.

Figure 5 shows our criteria for ranking dolomite occurrence potential, and plate 6 shows the distribution of potential. Because of past production, we typically categorized tracts having mapped Limestone of Cricket Mountains, Fish Haven Dolomite, or Laketown Dolomite as high occurrence potential for high-purity dolomite. We assigned a moderate occurrence potential to tracts with exposures of Sevy Dolomite, Simonson Dolomite, Guilmette Formation, or Wah Wah Summit Formation. Other mapped units that include dolomite in their lithologic descriptions but are not known for high-purity zones, such as many of the Permian Oquirrh Group exposures, were assigned a low occurrence potential. Because a dolomite deposit would need sufficient volume to be economic, in some cases we reduced the occurrence potential if the extent of an



Note: If extent of a unit with potential is limited within a tract, potential ranking was commonly reduced.

Figure 5 *. High-magnesium dolomite occurrence potential ranking system.*

exposure was limited or insignificant. Due to limited data for dolomite units in most areas of the UTTR, our certainty for occurrence potential for most dolomite-bearing tracts is low. In a few areas, where units are close to existing mines or favorable analytical data exists, our certainty ranking was higher. We assigned a high or moderate development potential to a few tracts near Graymont's operations. All other tracts having substantial high-magnesium dolomite potential were assigned a low development potential because of their remoteness.

Potash and Other Salts

Within the UTTR area, occurrence potential for potash and other salts, such as sodium and magnesium chloride, is primarily in shallow, near-surface brines of the playas and mudflats of the Great Salt Lake Desert. Currently, potash, sodium chloride, and magnesium chloride are extracted from shallow and deep subsurface brines on the west side of the Great Salt Lake Desert by Intrepid Potash. To evaluate the tracts, we used analytical data of brines from a number of sources including Nolan (1927), Nackowski (1962), and Kohler (2002). We focused on KCl content within the brine because potassium data are the most readily available and because potash is the most valuable potential brine commodity. We assume that brine enriched in potassium will also contain elevated levels of magnesium and sodium.

Figure 6 shows our criteria for evaluating occurrence potential for potash and other salts. We assigned high occurrence potential to tracts that had nearby analyses showing KCl content in the brine over 1.0%, moderate occurrence potential to tracts with nearby analyses showing KCl content from 0.5 to 1.0%, and low occurrence potential to tracts with nearby analyses showing KCl content less than 0.5% or to tracts with only sodium

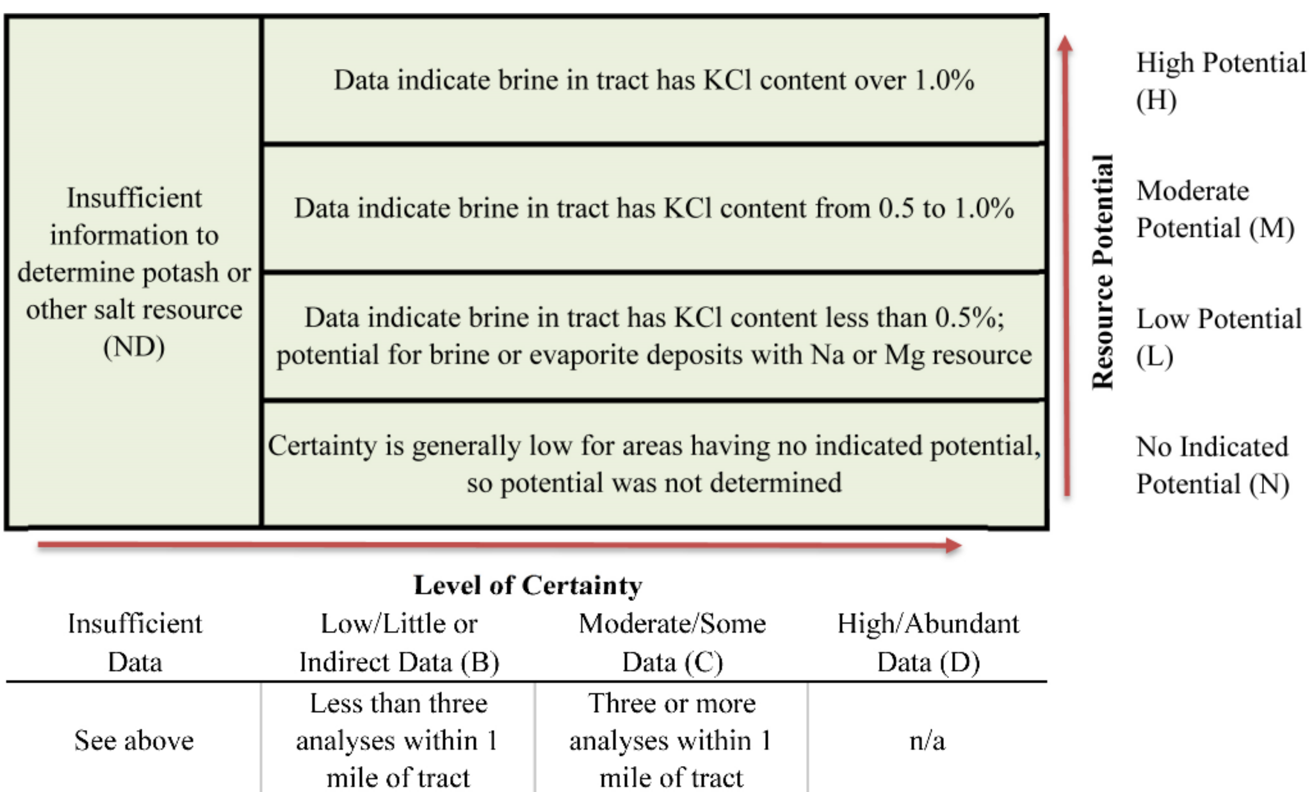


***Figure 6**. Potash and other salts occurrence potential ranking system.*

or magnesium salt potential. Our level of certainty was determined by the number of nearby analyses. No areas had what we considered to be abundant data, but we assigned a moderate certainty to tracts having at least three analyses within one mile of the border of the tract.

Most of the potash potential in the UTTR tracts lies in the basin and playa areas west and east of the Newfoundland Mountains and in the area between Interstate 80 and the Newfoundland Mountains (plate 7). Much of the brine data for these areas show elevated potassium chloride levels (0.5% KCl and higher), and the vast majority of the data predate the West Desert Pumping Project (WDPP) of the 1980s. Limited data from Kohler (2002) and Jones and others (2009) suggest that the shallow brine in these areas has been further enriched in potassium and other dissolved solids by addition of water from Great Salt Lake during the pumping project, so our determinations made from pre-WDPP data are likely conservative. Diking and ponding north of Interstate 80 in the following townships cast some uncertainty on our occurrence potential determinations in those areas: T. 1 N., R. 13 W.; T. 1 N., R. 12 W.; T. 1 S., R. 13 W. Descriptions and dynamics of the shallow brine aquifer in the Great Salt Lake Desert are discussed in Turk (1973), Lines (1979), Mason and Kipp (1998), and Rupke and Boden (2014). No known data are available for evaluation of deep subsurface brine resource in the area of the Great Salt Lake Desert, but some potential may exist at depth, particularly in areas where shallow brines show potential.

Some potential for salt (NaCl) is present at depth in the group of tracts north of Delta in T. 15 S., R. 7 W.; T. 15 S., R. 6 W.; and T. 16 S., R. 6 W. The shallowest known salt in the area is 2500 feet below the surface (Gwynn, 1989). Magnum is developing underground storage, primarily for gas, in the subsurface salt in the area. Salt may be a future byproduct of the operation, but we have assigned a low occurrence potential to this area because the salt is quite deep and likely uneconomic as a standalone product. Also, no known potash potential is associated with the deposits (Lindsey and others, 1981).

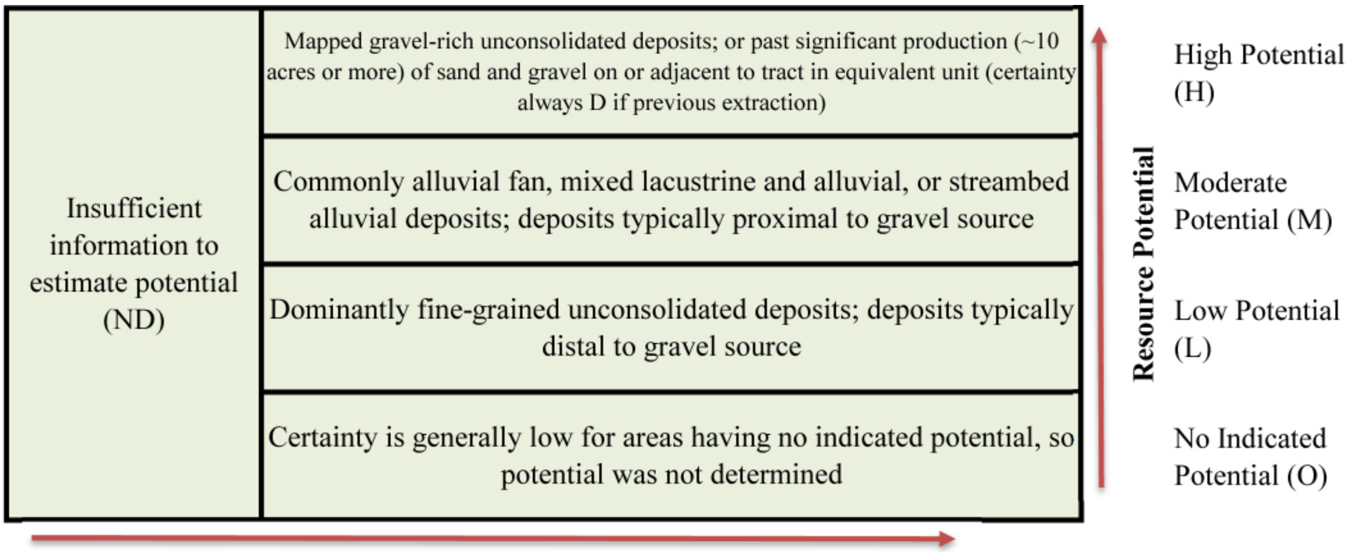
Development of brines or evaporites on the tracts in the UTTR exchange is unlikely. Although there has been ongoing potash exploration in Utah over the past decade, to date, no significant activity has focused on the area of these tracts. Therefore we have assigned potential as low in relation to potash or other salt development.

We considered evaluating lithium brine because the geologic setting suggests some limited occurrence potential, but essentially no useful data exist for the UTTR exchange area. Limited data from adjacent areas such as the Bonneville Salt Flats and Pilot Valley generally show grades below what is currently economic, and those brines are more enriched than what is found in the UTTR area. Also, the adjacent data indicate that the magnesium to lithium ratio is quite high, which would further reduce potential based on current extraction methods. These areas likely have a similar chemical evolution as playa areas in the UTTR, so component ratios are probably comparable.

Sand and Gravel

Sand and gravel occurrence potential is widespread in the UTTR exchange area, and much of that potential is in gravel-rich deposits that have either been modified and/or deposited by Lake Bonneville. The prominent shorelines of Lake Bonneville occur in a number of places throughout the project area (Curry and others, 1984).

Our basic criteria for assigning sand and gravel occurrence potential are shown in figure 7, and plate 8 shows where potential occurs. Typically, we gave a high occurrence potential to gravel-rich deposits (commonly



Level of Certainty

Insufficient Data	Low/Little or Indirect Data (B)	Moderate/Some Data (C)	High/Abundant Data (D)
See above	Data limited to available geologic mapping	Nearby data (commonly UMOS) or extraction	Signficant past extraction of sand and gravel on tract

Note: If extent of a potential unit is minimal within a tract, ranking was commonly reduced.

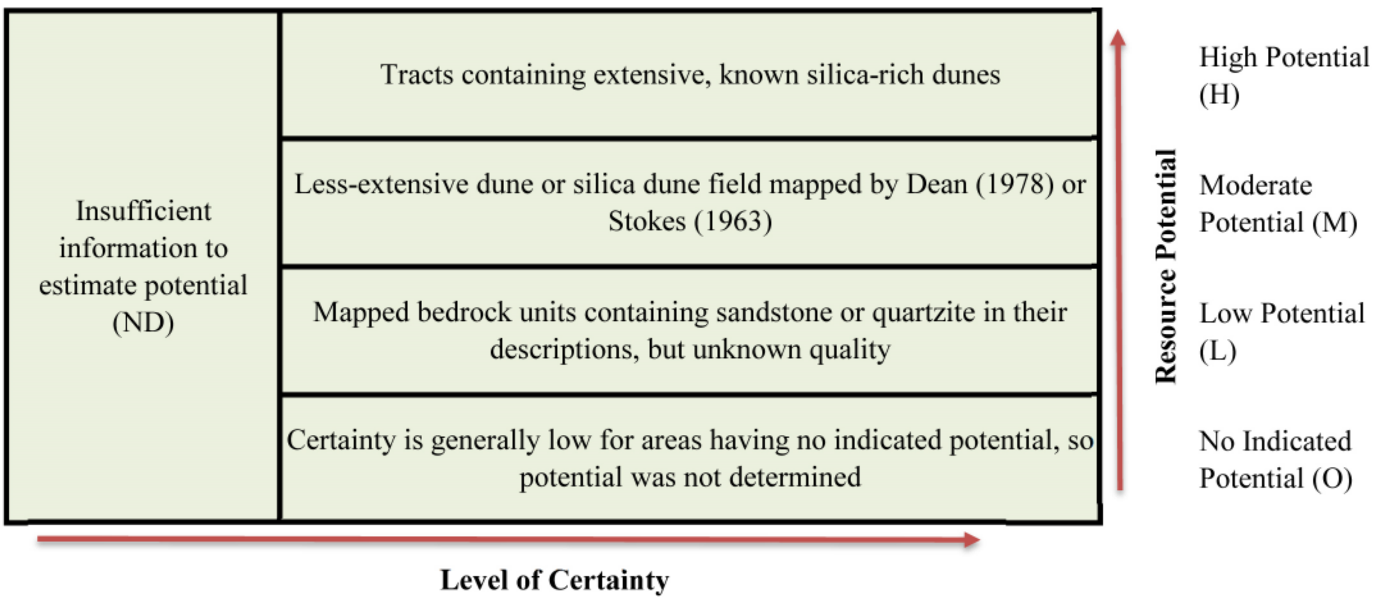
***Figure** 7. Sand and gravel occurrence potential ranking system.*

lacustrine in origin) or areas where substantial sand and gravel extraction already occurred. We considered a gravel quarry to have substantial extraction if the quarry footprint was about 10 acres or larger. Generally, we did not assign high potential to gravel-rich deposits unless they were geologically mapped at scales more detailed than 1:250,000. We assigned most alluvial-fan deposits, mixed lacustrine and alluvial deposits, and streambed deposits a moderate occurrence potential, as these types of deposits tend to contain more fines than gravel-rich lacustrine deposits. We typically assigned a low occurrence potential to eolian dune areas and fine-grained lacustrine deposits. We made no determination on mudflat or playa deposits, which likely have no potential for sand and gravel. Limited data are available on the quality of the sand and gravel resources throughout the area; however, quality can be inferred to some degree if nearby extraction has occurred on equivalent geologic units. UMOS provides information on past extractive locations, but rarely gives much indication of quality. The publication dates vary, but the Utah Department of Highways (UDOH) produced a series of materials inventory reports for each county during the 1960s (?). These UDOH reports provide some sieve data for sand and gravel deposits and occasionally provide an AASHTO ranking for sites. Some of these data were useful during our evaluation.

Like most of the evaluated industrial-mineral commodities, development potential for most areas is low due to remoteness of the deposits. However, we assigned moderate development potential to some of the tracts having moderate or high occurrence potential that are near areas of prior extraction, active leases, or significant roads.

Silica

Silica sourced from sand, sandstone, and quartzite is used in a variety of industrial applications. Common applications include hydraulic-fracturing sand (frac sand), foundry sand, glass-making sand, fillers, and others (Herron, 2006; Dolley, 2017). Occurrence potential for silica in the project area exists in silica-rich sand dunes, quartzite, and sandstone. Figure 8 shows our criteria for assigning silica occurrence potential, and plate 9 shows the tracts with potential. We generally assigned tracts with extensive, known silica-rich dunes a high occurrence potential. Moderate or low occurrence potential was generally assigned to less extensive dune fields or silica dune fields mapped by Dean (1978) or Stokes (1963) because of the low level of detail of the mapping. We considered other mapped bedrock units that contained sandstone or quartzite in their descriptions to have low potential for silica. Ordovician Eureka Quartzite, which is in a few tracts, has been mined elsewhere for silica for industrial purposes (Herron, 2006). However, we assigned tracts with Eureka Quartzite low occurrence potential because the exposures were so small. Other than a few chemical analyses of Eureka Quartzite, provided by the National Geochemical Database, that show high silica content, not much analytical data exists for other potentially silica-rich deposits in the UTTR exchange area. This, coupled with lack of production of silica in the area, puts our certainty level for areas that have silica occurrence potential as low.



Insufficient Data (A)	Low/Little or Indirect Data (B)	Moderate/Some Data (C)	High/Abundant Data (D)
See above	Data limited to available geologic mapping	n/a	n/a

Note: If extent of a potential unit is minimal within a tract, ranking was commonly reduced.

Figure 8 *. Silica occurrence potential ranking system.*

Given lack of past activity, we consider development potential of silica resources on UTTR tracts to be low. Although there has been some frac sand exploration activity in Utah in the past several years, we are aware of no significant interest in deposits within the UTTR area.

METALLIC MINERALS

The majority of the metal mines and mining districts in the Great Basin of western Utah are associated with and mostly centered on igneous stocks. UTTR exchange tracts with metallic mineral potential lie in or near, from north to south, the Newfoundland, Stockton, Ophir, Gold Hill, Granite Peak, Fish Springs, Honeycomb Hills, and Drum Mountains mining districts. The general character of these districts and the UTTR tracts of interest are discussed briefly below. Most of the rated tracts have low development potential. Plate 10 shows the UTTR exchange tracts with occurrence and development ratings for metals.

Newfoundland Mining District

The Newfoundland district occupies the north end of the desolate Newfoundland Mountains in south-central Box Elder County. Early production came from Ag-Cu-Pb veins in the early 1900s and mining activity resumed in the 1950s when small lots of W and Cu were produced (Doelling, 1980). In terms of metal values, the Newfoundland district has minor production of W (~85% of production value) and lesser Ag-Cu ±Pb ores.

The Newfoundland Mountains are a 19-mile-long, north-trending range consisting of generally west-dipping Paleozoic rocks that have been intruded by one large (~10 sq mi), Late Jurassic (150 Ma) quartz monzonite stock and three smaller plugs and numerous associated dikes to the south (Allmendinger and Jordan, 1984). Regional aeromagnetic surveys suggest that these outliers connect to the main stock at depth and the main stock also probably underlies some of the pediment west of Miners Basin. The stocks are generally light-colored, porphyritic, biotite-hornblende quartz monzonite. The largest stock ranges in texture and composition from dark, coarse-grained, porphyritic granodiorite along the margins to a lighter-colored, finer grained, more equigranular, quartz monzonite core. The core of the larger stock and the entire smaller, south-central stock are both weakly, but pervasively altered to clay-chlorite (Allmendinger and Jordan, 1984). The dikes are generally biotite-feldspar latite porphyries, trend either northeast or northwest, and are locally altered and associated with mineralization.

Mineralization in the Newfoundland district can be divided into two broad types: W skarns and polymetallic quartz veins. Tungsten mineralization occurs within the contact metamorphic aureole of the plugs, mostly marble and hornfels, and is generally hosted in the Ordovician Garden City Limestone (Everett, 1961). Small scheelite lenses occur in garnet skarn, mainly adjoining the south-central stock. Tungsten, in the form of wolframite, is also reported from the Copper Flat area to the northeast of the large stock (Doelling, 1980).

The Ag-Cu ±Pb ores occur in narrow, northwest-trending quartz veins typically about a mile from the stocks. Bismuthinite is reported from the Stone House Cu-Ag veins in Miners Basin on the west side of the range. A few scattered base metal prospects also occur a few miles south of the main portion of the district.

Section 2, T. 5 N., R. 15 W. lies on the west flank of the range and west of a couple of abandoned Cu-Ag-Au-Pb ±Bi mines in Miners Basin. This section is rated as having moderate potential at a low level of certainty for Cu-Ag-Au-Pb with low development potential.

Stockton Mining District

The Stockton mining district is located 11 miles southwest of Bingham on the west slope of the Oquirrh Mountains in easternmost Tooele County. Stockton is one of the oldest districts in Utah, mining dates back to the mid-1860s and lasted nearly continuously until 1958. The total production from Stockton is roughly 2.2 million tons of ore averaging 7.7% Pb, 2.7% Zn, 0.3% Cu, 157 ppm Ag, and 1.27 ppm Au, recovered, making it about the tenth most productive mining district in Utah and the fifth largest Pb and Zn producer.

Stockton is an intrusive-centered mining district in the Bingham-Park City mineral belt and the Oquirrh Mountains are one of the easternmost ranges in the Basin and Range. The manto-style replacement mineralization developed by the Stockton underground mines is hosted by a thick sequence of alternating dark-gray limestone and light-gray quartz sandstone of the Pennsylvanian Oquirrh Group. The strata dip steeply north and are cut by west-dipping faults and mineralized fissures (James and Atkinson, 2006). The intersection of the favorable limestone and the mineralizing fissures has produced about 80 small, steeply north-northwest-plunging, ribbon-like, massive sulfide replacement deposits, typically 3 to 10 ft thick, about 10 to 80 ft wide along strike, and plunging several hundreds of feet down dip.

The sedimentary sequence is intruded by a melanocratic, fine- to medium-grained, equigranular, strongly magnetic, augite-hornblende-biotite monzonitic, sill-like Spring Gulch stock and younger north-trending, fine-grained, biotite-quartz latite Raddatz porphyry dikes, which are characterized by large K-spar phenocrysts that have been dated at 39.4 ± 0.34 Ma (Krahulec, 2014). These igneous rocks are compositionally very similar to the early melanocratic Last Chance monzonite stock and late quartz latite porphyry dike phases at Bingham. Porphyry Cu mineralization was discovered in the pediment southwest of the district by Kennecott in 1996. The Stockton porphyry system is a quartz monzonite porphyry Cu-Au-Mo system, similar to Bingham, but with lower grade and at moderate depth (>1000 ft).

Three adjoining tracts on the southeast edge of the Stockton district were rated low or moderate occurrence potential with low certainty for Pb-Ag and all have low development potential (sections 27, 28, and 29, T. 4 S., R. 4. W.)

Ophir Mining District

The Ophir mining district is located in the southwestern Oquirrh Mountains, about 33 mi south-southwest of Salt Lake City. The Ophir district was organized in the 1860s as a bonanza Ag camp and mining continued sporadically into the early 1970s. The Ophir district is about the ninth most productive in Utah. Ophir is credited with production of about 2.8 million tons of ore averaging 6.2% Pb, 1.5% Zn, 0.8% Cu, 237 ppm Ag, and 0.21 Au, recovered. The Ophir Hill Ag-Pb-Zn -Cu distal skarn in Ophir Canyon is the largest producer in the district with about 1.5 million tons of production (Rubright, 1978).

The southwestern Oquirrh Mountains are geologically dominated by the Ophir anticline. This fold is part of a north-northwest-trending, Mesozoic fold belt characterized by thrust-cored, asymmetrical, closed anticlines and synclines, and has a wavelength of about 35,000 ft and amplitude of 15,000 ft.

Mineralization in the Ophir district is largely confined to a northwest-trending belt less than 1 mile wide and over 3 miles long, approximately coincident with the crest of the Ophir anticline. The ore deposits of the Ophir district are dominantly distal skarns, carbonate replacement deposits, and veins. The dominant ore controls are the intersections of north-trending fissures and favorable host horizons, namely the Cambrian Ophir Formation, Mississippian Gardison Limestone, and Mississippian lower Great Blue Limestone. A series of poorly exposed Eocene monzonite plugs, dikes, and sills intrude near the anticlinal crest and may be related to ore.

The Ophir district is unusual because it is in part a vertically zoned mining district (Krahulec, 2015). Past production ranges from distal, sediment-hosted Ag-Au-Pb deposits high on Lion Hill to the south, through medial, Pb-Zn-Ag carbonate replacement deposits in Dry Canyon to the north, to Pb-Cu-Ag-Zn distal skarns in the bottom of Ophir Canyon and continuing under Dry Canyon. The primary ore/sulfide minerals in the district are argentite, chalcopyrite, galena, pyrite, pyrrhotite, sphalerite, and tetrahedrite. Wolframite [$(Fe,Mn)WO_4$] is reported from the Ophir Hill and a few other mines in the district. Some small historical mineral resources remain in some of the old mines. Several companies have explored the Ophir district for a porphyry Cu system similar to those in the adjoining Bingham and Stockton districts, but no noteworthy results are reported.

Four partial section tracts located in the northeast corner of the district have been rated moderate occurrence potential with low to moderate certainty for either Pb-Zn-Ag or Pb-Zn-Cu-Ag and have low development potential (sections 11, 13, and 14, T. 5 S., R. 4 W.).

Gold Hill Mining District

The Gold Hill district lies near the Nevada state line in west-central Tooele County. Gold Hill is a large As-Au-Ag-Pb-Cu district and is both the largest As and W producing district in the state. Production from the district peaked during World War I, after the arrival of a railroad from Wendover. The two largest producers in the district are believed to be the Gold Hill (Western Utah) and U.S. arsenic mines.

The Gold Hill district is structurally complex and hosts an unusual suite of ore deposits including polymetallic pipe, skarn, vein, and replacement deposits. Most of the Gold Hill ore deposits are associated with a large (22 sq mi) Jurassic granodiorite plug (about 152 Ma). The polymetallic pipes are small, irregular, W-Cu-Mo-bearing chimneys of very coarse grained actinolite-tourmaline-orthoclase formed within the Jurassic granodiorite (e.g., Yellow Hammer mine). The skarns (Cu-W-As-Mo-Pb-Zn-Bi-Sb-Au) form in carbonates adjacent to the granodiorite stock and occur as prograde garnet-diopside and retrograde hornblende-actinolite-tourmaline skarns. These include a few small Au skarns like the Midas and Cane Springs orebodies. The largest historical producers in the district are the arsenopyrite polymetallic vein and replacement deposits (Gold Hill and U.S. mines) formed in the Mississippian Ochre Mountain Limestone near the Jurassic granodiorite. These As-Pb-Cu-Zn-Sb bodies lie just outboard of the skarns and are controlled by the intersection of mineralizing fissures and favorable host beds (Nolan, 1935).

Later mineralizing events in the Gold Hill district include W skarns associated with the Eocene (about 42 Ma) quartz monzonite plug (4 sq mi) north of Gold Hill, and the Stardust and Timm mines are the largest producers. There are also some small polymetallic (Pb-Ag-Cu-Au) vein and replacement deposits spatially associated with this quartz monzonite plug. A third mineralizing event is the Miocene (~8 Ma) low sulfidation Au quartz-adularia vein stockwork (~50,000 ounces Au) in Rodenhouse Wash at the Kiewit property which was briefly (2014-16) in production (Robinson, 2006).

Five tracts in the pediment along the eastern flank of the Gold Hill district have been rated low occurrence potential with low certainty to moderate occurrence potential with moderate certainty for As-Au-Ag-Pb-Cu, W, or Cu-Au-Ag (section 36, T. 6 S., R. 18 W.; section 16, T. 7 S., R. 17 W.; sections 2, 33, and 34, T. 8 S., R. 17 W.). All have low development potential.

Granite Peak Mining District

The Granite Peak (Granite Range) mining district is located about 85 miles west of Provo in south-central Tooele County. The district is an insignificant Pb-Ag producer and has some fluorite production. The El Dorado mine is believed to be the largest producer.

Granite Peak is principally composed of an exposed 25-square-miles Jurassic (about 149 Ma) granite-granodiorite complex (Clark and others, 2009). The upper part of the complex is a foliated granodiorite underlain by a more leucocratic granite. Both intrusive phases are cut by pegmatite and aplite dikes and quartz veins.

Pegmatite dikes are common throughout the Granite Peak intrusive complex and are estimated to form from 10% to 15% of the intrusive rock volume, being more prevalent in the upper foliated granodiorite. The pegmatite dikes typically strike approximately N. 35° E. and dip 55° to 70° W. The pegmatites range from small stringers, to pods, to larger tabular, zoned dikes with some individual dikes traced for up to half a mile. The pegmatites are composed of coarse aggregates of quartz, microcline, plagioclase, and muscovite. Accessory minerals generally constitute about 1% of the pegmatites and the minerals include garnet, tourmaline, beryl, samarskite, zircon, apatite, and hematite. The three zones within the pegmatites are termed borderwall, intermediate, and core. Samarskite and beryl occur in greatest abundance at the inner margin of the intermediate zone, adjoining the quartz-dominant core. The core is reportedly 97% quartz and 2% microcline (Fowkes, 1964). The Desert Queen prospect on the west side of Desert Peak was briefly examined by the Mica Corporation of America in the 1940s for muscovite having some books up to 6 inches across.

Mineralization at the El Dorado mine occurs in a north-trending, steeply east-dipping quartz vein. The vein is in a fault which it shares with a green, medium-grained, "diorite" dike. The dike is altered to chlorite-sericite-pyrite (Butler and others, 1920). Both the hanging wall and footwall of the fault are leucocratic granite. Butler and others (1920) believe that the dike predates the vein and Clark and others (2009) report the dike is Miocene (~8 Ma). The quartz vein is banded and contains galena, chalcopyrite, fluorite, and some Ag-Au values (Butler and others, 1920).

Two tracts in the pediment north of the Granite Peak district, an area that has a corresponding aeromagnetic high that is partly coincident with the outcropping intrusive complex, have been rated low to moderate occurrence potential with low certainty Pb-Ag or fluorite and low development potential (section 32, T. 7 S., R. 12 W. and section 36, T. 7 S., R. 13 W.).

Fish Springs Mining District

The Fish Springs district is located in northwestern Juab County about 72 miles west of Eureka. The district was organized in 1891 and was a significant Ag-Pb producer into the early 1960s. The Utah and Galena Pb -Ag mines are by far the largest historical producers in the district. A large Zn skarn (West Desert - Crypto) was discovered at depth by drilling in the late 1950s and early 1960s.

Mineralization at Fish Springs is associated with west-northwest-trending fracture zones and trachyte dikes along the Juab fault, as well as a concealed, Eocene, equigranular to weakly porphyritic, monzonite-syenite stock dated at 38.5 ±1.0 Ma (Staargaard, 2009). Previously mined mineralization is primarily vein and replacement ores in the Silurian Laketown dolomite. These replacement ores are strongly anomalous in As, B, Cd, Mn, Mo, V, and Zn.

Disseminated Ag-Pb mineralization at the Cactus mine, two miles south of the main district, is hosted by an Ordovician, friable, calcareous, quartz sandstone, mapped as Eureka Quartzite, but is likely the underlying Watson Ranch Quartzite. The overall trend of this mineralization is about N. 20° E. The mineralized zone is about 100 ft wide on the surface and may be traced intermittently along strike for about 3000 ft to the northeast. High-grade rock-chip sampling of this mineralized zone averages about 200 ppm Ag and 8% Pb.

Bleaching and recrystallization of the carbonates along the northwestern range front and a very strong aeromagnetic high, led to drill testing of the pediment and the discovery of the West Desert unexposed stock and a magnetite-sphalerite skarn (Christiansen, 1977). The magnesian skarn consists of medium- to coarse-grained humite, magnetite -magnesioferrite, and phlogopite along with lesser spinel, periclase, actinolite/tremolite, and forsterite. The sulfide phases present in the skarn include sphalerite, chalcopyrite, molybdenite, pyrite, and lesser pyrrhotite and roquesite ($CuInS_2$) (Staargaard, 2009).

In 1993, Cyprus reported two separate resource estimates at West Desert: 3.1 million tons of 7.0% Zn as an oxide deposit and 6 million tons of 8.7% Zn in a deeper sulfide deposit (Staargaard, 2009). More recent drilling on the deposit by InZinc (Lithic Resources) has revealed economically interesting indium is associated with the sphalerite skarn, including 78.3 ft assaying 4.22% Zn and 184.9 ppm In in hole C-07-01.

Three tracts in the pediment southwest and west of the Fish Springs district are rated low to moderate occurrence potential and low certainty for Ag-Pb-Zn ±Au with low development potential (sections 16 and 36 T. 11 S., R. 15 W. and section 2, T. 12 S., R. 15 W.).

Honeycomb Hills Mining District

The Honeycomb Hills district is located about 59 miles northwest of Delta in west-central Juab County. The area has no recorded production, but has been prospected intermittently since the 1950s for lithophile elements including U, Be, Li, and REE. The Honeycomb Hills are part of a low range of hills between the southern Deep Creek Range to the west and the Fish Springs Range to the east.

Volcanic-hosted U mineralization was discovered in the Honeycomb Hills by H.P. Bertelsen in 1950, but grades were below typical economic U ore concentrations (<0.1% U_3O_8). In 1961, C.R. Sewell discovered Be mineralization in the area while working for The Dow Chemical Co. Dow drilled a series of 15 exploration holes totaling 2930 ft and cut some dozer trenches. Assays reported ran from 0.05% to 0.85% Be (McAnulty and Levinson, 1964). Later, Anaconda held a property position in the district from 1977 to 1979 while exploring for U. ATW Gold Corp. acquired the Honeycomb Hills as a REE prospect in 2010. ATW Gold reported surface samples running up to 1000 ppm Be, 1690 ppm Li, 1270 ppm Rb, and 1043 ppm total rare earth oxides.

The Honeycomb Hills are the westernmost Miocene to Pliocene (22 to 4 Ma) topaz rhyolite along the greater Tintic mineral belt. This belt includes the famous Spor Mountain Be-F district 20 miles to the east. The Honeycomb Hills volcanic complex consists of a 40-ft-thick, Pliocene lithic, fluorite-bearing, ash-flow tuff, immediately underlain by older volcanic rocks, and overlain by two coeval topaz rhyolite flow domes that erupted about 4.7 Ma. The rhyolite is gray, vesicular, strongly flow-banded, and contains about 40% phenocrysts of smoky quartz, sanidine, plagioclase, and biotite. Topaz crystals commonly line the vesicles. The rhyolite also contains globular topaz- and fluorite-bearing inclusions (Christiansen and others, 1986). Paleozoic carbonates (Devonian?) are estimated to underlie the volcanic domes at a depth of about 200 ft (McAnulty and Levinson, 1964).

The Honeycomb Hills property hosts a variety of unusual and possibly REE-bearing minerals including: autunite, boltwoodite, fluorite, ralstonite, saléeite, sklodowskite, soddyite, thomsenolite, tridymite, uranophane, and possibly bertrandite. Low-grade Be, Li, Cs, and Rb occurs in an approximately 3-ft-thick zone in the uppermost tuff immediately underlying the capping massive Bell Hill (northwestern) rhyolite dome (McAnulty and Levinson, 1964). Some samples also contain weakly anomalous Mo and Sn (Christiansen and others, 1986). In addition, the Honeycomb Hills are anomalous in Lu, Tb, Y, and Yb with a low LREE/HREE ratio (i.e., it is relatively enriched in HREE).

Several tracts lie in the pediment adjoining the Honeycomb Hills district in an area that is partly coincident with the outcropping intrusive/volcanic complex. These SITLA tracts (section 32, T. 12 S., R. 15 W.; section 16, T. 13 S., R. 15 W.; section 36, T. 12 S., R. 16 W.; and section 2, T. 13 S., R. 16 W.) are rated as low occurrence potential and low certainty for Be-Li ±F with low development potential.

Drum Mountains Mining District

The Drum Mountains (Detroit) mining district straddles the Juab-Millard County line in west-central Utah, 28 miles northwest of Delta. The district is a large Au and Mn producer with lesser Cu. The district has a long history of exploration and development. The total value of district production is well over $100 million, at 2014 metal prices. The Drum Mountains Au mines in the south are the largest producers.

The Drum Mountains are broadly part of the east-west-trending Tintic mineral belt in the Basin and Range Province of west-central Utah. The Drum Mountains are a small range consisting of moderately west- to southwest-dipping Proterozoic-Ordovician sedimentary strata overlain by a series of Eocene and Oligocene volcanic rocks. Mineralization in the district is related to the Eocene (~36 Ma) Mt. Laird quartz monzonite porphyry stocks and dikes. The district contains a small, subeconomic porphyry Mo-Cu system (USGS Model 21b) and a series of adjoining small Cu-Au-Ag carbonate replacement deposits in the Cambrian strata to the west. The porphyry Mo-Cu deposit has a small, low-grade, supergene chalcocite blanket. The Cu-Au-Ag replacement deposits are believed to have a primary mineralogy of chalcopyrite, pyrite, tetrahedrite, native bismuth, argentite, and possibly pyrrhotite. The Cu-Au-Ag ores are also anomalous in As, Bi, Hg, Sb, Sn, and Te.

The central Mo-Cu and Cu-Au-Ag deposits are flanked to the south by the Drum Mountains distal disseminated gold mines (USGS Model 19c) and to the north by manganese replacement deposits (USGS Model 19b), the first and second most productive mines in the district, respectively. The Drum Mountains gold mines are weakly anomalous in As, Bi, and Sb (Krahulec, 2011). The primary ore/sulfide minerals in the Mn replacement deposits are rhodochrosite, mangoan calcite, pyrite, and galena (Crittenden and others, 1961). These Mn ores may be geochemically anomalous in As, Pb, and Zn.

A block of 13 contiguous tracts in the central Drum Mountains are rated L/B to H/D for a variety of metals including Au, Ag, Mn, Cu, and Pb, including section 31, T. 14 S., R. 10 W.; sections 25, 26, 27, 34, and 35, T. 14 S., R. 11 W.; section 6 and 7, T. 15 S., R. 10 W.; and sections 1, 3, 11, 12, and 13, T. 15 S., R. 11 W. Two outlying tracts in the pediment five miles northeast of the main district are rated low occurrence potential with moderate certainty for Ag-Pb at depth (sections 3 and 10, T. 14 S., R. 10 W.). Most of these tracts have low development potential, but three tracts in the central Drum Mountains district have moderate development potential and one has high development potential.

SUMMARY

Mineral potential for clay, crushed stone, gypsum, high-calcium limestone, high-magnesium dolomite, potash and other salts, sand and gravel, silica, and metals exists on some of the 356 BLM and SITLA tracts nominated for exchange within the Utah Test and Training Range area. The most significant commodities within the exchange tracts are probably high-calcium limestone and high-magnesium dolomite in the area of an active lime operation in the Cricket Mountains operated by Graymont. We also anticipate potential for development of gypsum, crushed stone, sand and gravel, and metals on some of the exchange tracts. Our findings are summarized in table ES-1.

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REFERENCES

Allmendinger, R.W., and Jordan, T.E., 1984, Mesozoic structure of the Newfoundland Mountains, Utah— horizontal shortening and subsequent extension in the hinterland of the Sevier Belt: Geological Society of America Bulletin, v. 95, p. 1280-1292.

Allmendinger, R.W., and Jordan, T.E., 1989, Geologic map of the Newfoundland Mountains, northwestern Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2087, scale 1:31,680.

Armstrong, R.L., 1968, Sevier orogenic belt in Nevada and Utah: Geological Society of America Bulletin, v. 79, p. 429-458.

Best, M.G., Barr, D.L., Christiansen, E.H., Gromme, C.S., Deino, A.L., and Tingey, D.G., 2009, The Great Basin altiplano during the middle Cenozoic ignimbrite flareup—Insights from volcanic rocks: International Geology Review, v. 51, p. 589-633.

Boden, T., 2010, Gypsiferous sand dune deposits on SITLA lands in the Great Salt Lake Desert project area, Tooele County, Utah: unpublished report prepared for SITLA by the Utah Geological Survey, variously paginated, 1 plate.

Boden, T., Krahulec, K., Vanden Berg, M., and Rupke, A., 2016, Utah's extractive resource industries 2015: Utah Geological Survey Circular 123, 33 p.

Boleneus, D.E., 2008, Building stone quarries and yards, Utah and parts of Arizona, Idaho, Montana, Washington, and Wyoming: Utah Geological Survey Open-File Report 521, unpaginated with 3 plates.

Butler, B.S., Loughlin, G.F., Heikes, V.C.

and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.
Christiansen, E.H., Sheridan, M.F., and Burt, D.M., 1986, The geology and geochemistry of Cenozoic topaz rhyolites from the western United States: Geological Society of America Special Paper 205, 82 p.
Christiansen, W.J., 1977, Geology of the Fish Springs mining district, Juab County, Utah: Salt Lake City, University of Utah, M.S. thesis, 66 p.
Clark, D.L., Biek, R.F., Willis, G.C., Brown, K.D., Kuehne, P.A., Ehler, J.B., and Ege, C.L., 2009, Geologic map of the Granite Peak and Sapphire Mountain area, U.S. Army Dugway Proving Ground, Tooele County, Utah: Utah Geological Survey Map 238, scale 1:24,000.
Clark, D.L., Kirby, S.M., and Oviatt, C.G., 2012, Interim geologic map of the Rush Valley 30' x 60' quadrangle, Tooele, Utah, and Salt Lake Counties, Utah: Utah Geological Survey Open-File Report 593, scale 1:62,500.
Clark, D.L., Oviatt, C.G., and Dinter, D.A., 2016, Interim geologic map of parts of the Tooele 30' x 60' quadrangle, Tooele, Salt Lake, and Davis Counties, Utah—year 3: Utah Geological Survey Open-File Report 656, scale 1:62,500.
Clark, D.L., Oviatt, C.G., and Page, D., 2008, Interim geologic map of Dugway Proving Ground and adjacent areas, parts of Wildcat Mountain, Rush Valley, and Fish Springs 30' x 60' quadrangles, Tooele County, Utah (year 2 of 2): Utah Geological Survey Open-File Report 532, scale 1:75,000.
Crangle, R.D., 2017, Gypsum, *in* U.S. Geological Survey, mineral commodity summaries: Online, https://minerals.usgs.gov/minerals/pubs/commodity/gypsum/mcs-2017-gypsu.pdf, accessed April 2017.
Crittenden, M.D., Jr., Straczek, J.A., and Roberts, R.J.U., 1961, Manganese deposits in the Drum Mountains, Juab and Millard Counties, Utah: U.S. Geological Survey Bulletin 1082-H, pp. 493-544.
Curry, D.R., Atwood, G., and Mabey, D.R., 1984, Major levels of Great Salt Lake and Lake Bonneville: Utah Geological and Mineral Survey Map 73, scale 1:750,000.
Dean, L.E., 1976, Eolian sand dunes of the Great Salt Lake Desert region, Utah: Salt Lake City, University of Utah, M.S. thesis, 138 p., 2 plates, scale 1:250,000.
Dean, L.E., 1978, Eolian sand dunes of the Great Salt Lake Basin: Utah Geological and Mineral Survey, Utah Geology, v. 5, no. 2, p. 103-111.
Doelling, H.H., 1980, Geology and mineral resources of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p., 3 plates, scale 1:125,000.
Doelling, H.H., Solomon, B.J., and Davies, S.F., 1994, Geologic map of the Grayback Hills quadrangle, Tooele Co., Utah: Utah Geological Survey Map 166, scale 1:24,000.
Dolley, T.P., 2017, Sand and gravel (industrial), *in* U.S. Geological Survey, mineral commodity summaries: Online, https://minerals.usgs.gov/minerals/pubs/commodity/silica/mcs-2017-sandi.pdf, accessed April 2017.
Eardley, A.J., 1962, Gypsum dunes and evaporite history of the Great Salt Lake Desert: Utah Geological and Mineralogical Survey Special Study 2, 27 p.
Everett, F.D., 1961, Tungsten deposits in Utah: U.S. Bureau of Mines Information Circular 8014, 43 p.
Fowkes, E.J., 1964, Pegmatites of Granite Peak Mountain, Tooele County, Utah: Brigham Young University Geology Studies, v. 11, p. 97–125.
Grim, R.E., 1953, Clay mineralogy: New

York, McGraw-Hill, 384 p.
Gwynn, J.W., 1989, The saline resources of Utah: Utah Geological Survey Survey Notes, v. 23, no. 3, p. 21-31.
Herron, S., 2006, Industrial sand and sandstone, in Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., editors, Industrial minerals and rocks—commodities, markets, and uses, 7th Edition: Society for Mining, Metallurgy, and Exploration, Inc., p. 815-832.
Hintze, L.F., 1980, Preliminary geologic map of the Fish Springs NW and Fish Springs SW quadrangle, Juab and Tooele Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1148, scale 1:24,000.
Hintze, L.F., and Davis, F.D., 2002a, Geologic map of the Delta 30' x 60' quadrangle and part of the Lynndyl 30' x 60' quadrangle, northeast Millard County and parts of Juab, Sanpete, and Sevier Counties, Utah: Utah Geological Survey Map 184, scale 1:100,000
Hintze, L.F., and Davis, F.D., 2002b, Geologic map of the Tule Valley 30' x 60' quadrangle and parts of the Ely, Fish Springs, and Kern Mountains 30' x 60' quadrangles, northwest Millard County, Utah: Utah Geological Survey Map 186, scale 1:100,000.
Hintze, L.F., and Davis, F.D., 2002c, Geologic map of the Wah Wah Mountains north 30' x 60' quadrangle and part of the Garrison 30' x 60' quadrangle, southwest Millard County and part of Beaver County, Utah: Utah Geological Survey Map 182, scale 1:100,000.
Hintze, L.F., Davis, F.D., Rowley, P.D., Cunningham, C.G., Steven, T.A., and Willis, G.C., 2003, Geologic map of the Richfield 30' x 60' quadrangle, southeast Millard County and parts of Beaver, Piute, and Sevier Counties, Utah: Utah Geological Survey Map 195, scale 1:100,000.
Hintze, L.F., and Kowallis, B.J., 2009, Geologic history of Utah: Provo, Utah, Brigham Young University Geology Studies, Special Publication 9, 225 p.
Hintze, L.F., Willis, G.C., Laes, D.Y., Sprinkel, D.A., and Brown, K.D., 2000, Digital geological map of Utah: Utah Geological Survey Map 179DM, scale 1:500,000, compact disk.
James, L.P., and Atkinson, W.W., Jr., 2006, The Rush Valley mining district, Stockton Quadrangle, Tooele County, Utah, *in* Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 94-120.
Jones, B.F., White, W.W. III, Conko, K.M., Webster, D.M., and Kohler, J.F., 2009, Mineralogy and fluid chemistry of surficial sediments in the Newfoundland Basin, Tooele and Box Elder Counties, Utah: Utah Geological Survey Open-File Report 539, 96 p.
Kohler, J.F., 2002, Effects of the West Desert Pumping Project on the near-surface brines in a portion of the Great Salt Lake Desert, Tooele and Box Elder Counties, Utah, in Gwynn, J.W., editor, Great Salt Lake—an overview of change: Utah Department of Natural Resources Special Publication, p. 487-498.
Krahulec, K., 2011, Sedimentary rock-hosted gold and silver deposits of the northeastern Basin and Range, Utah, *in* Steininger, R., and Pennell, B, editors, Great Basin evolution and metallogeny: Geological Society of Nevada 2010 Symposium Volume I, p. 31-62.
Krahulec, K., 2014, Discovery of the Stockton porphyry copper system, Stockton mining district, Tooele County, Utah: Society of Economic Geologists Guidebook 41, p. 37-50.
Krahulec, K., 2015, Tertiary intrusion-related copper, molybdenum, and tungsten mining districts of the eastern Great

Basin, *in* Pennell, W.M., and Garside, L.J., editors, New Concepts and Discoveries: Geological Society of Nevada 2015 Symposium CD, p. 219-250.

Lindsey, D.A., Glanzman, R.K., Naeser, C.W., and Nichols, D.J., 1981, Upper Oligocene evaporites in basin fill of Sevier Desert region, western Utah: American Association of Petroleum Geologists Bulletin, v. 65, p. 251-260.

Lines, G.C., 1979, Hydrology and surface morphology of the Bonneville Salt Flats and Pilot Valley playa, Utah: U.S. Geological Survey Water-Supply Paper 2057, 107 p.

Mason, J.L., and Kipp, K.L., Jr., 1998, Hydrology of the Bonneville Salt Flats, northwestern Utah, and simulation of ground-water flow and solute transport in the shallow-brine aquifer: U.S. Geological Survey Professional Paper 1585, 108 p.

McAnulty, W.N., and Levinson, A.A., 1964, Rare alkali and beryllium mineralization in volcanic tuffs, Honey Comb Hills, Juab County, Utah: Economic Geology, v. 59, 768-774.

Miller, D.M., Clark, D.L., Wells, M.L., Oviatt, C.G., Felger, T.J., and Todd, V.R., 2012, Progress report geologic map of the Grouse Creek 30' x 60' quadrangle and Utah part of the Jackpot 30' x 60' quadrangle, Box Elder County, Utah, and Cassia County, Idaho (Year 3 of 4): Utah Geological Survey Open-File Report 598, scale 1:62,500.

Morris, H.T., 1964, Limestone and dolomite, in Hilpert, L.S., editor, Mineral and water resources of Utah: Report of the U.S. Geological Survey to the U.S. Senate Committee on Interior and Insular Affairs, document no. 91-12, p. 188-194.

Nackowski, M.P., 1962, Brine exploration—Bonneville Salt Flats: unpublished report prepared for Bonneville Limited, 50 p., 1 plate.

Nolan, T.B., 1927, Potash brines in the Great Salt Lake Desert: U.S. Geological Survey Bulletin 795-B, 44 p.

Nolan, T.B., 1935, The Gold Hill mining district, Utah: U.S. Geological Survey Professional Paper 177, 172 p.

Pampeyan, E.H., 1989, Geologic map of the Lynndyl 30- by 60-minute quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1830, scale 1:100,000.

Solomon, B.J., 1993, Quaternary geologic maps of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah: Utah Geological Survey Open-File Report 296, 48 p. pamphlet, scale 1:24,000.

Presnell, R.D., 1997, Structural controls on the plutonism and metallogeny in the Wasatch and Oquirrh Mountains, Utah, *in* John, D.A., and Ballantyne, G.H., editors, Geology and ore deposits of the Oquirrh and central Wasatch Mountains, Utah: Society of Economic Geologists Guidebook, v. 29, p. 1-10.

Presnell, R.D., and Parry, W.T., 1995, Evidence of Jurassic tectonism from the Barneys Canyon gold deposit, *in* Miller, D.M. and Busby, C., editors, Jurassic magmatism and tectonics of the North America Cordillera: Geological Society of America Special Paper 299, p. 313-326.

Robinson, J.P., 1993, Provisional geologic map of the Gold Hill quadrangle, Tooele County, Utah: Utah Geological Survey Map 140, scale 1:24,000.

Robinson, J.P., 2006, Gold Hill, Utah—polyphase, polymetallic mineralization in a transverse zone, *in* Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, 16 p.

Rubright, R.D., 1978, Geology of the Ophir district, Utah, *in* Shawe, D.R., and

Rowley, P.D., editors, Guidebook to mineral deposits of southwestern Utah: Utah Geological Association Publication 7, p. 35-40.

Rupke, A., and Boden, T., 2014, Pilot Valley potash potential: unpublished report prepared by the Utah Geological Survey for the Utah School and Institutional Trust Lands Administration, 24p., 2 appendices.

Rupke, A., Krahulec, K., and Boden, T., 2014, Mineral resource potential of state land parcels selected for the West Desert Exchange, Box Elder, Tooele, and Juab Counties, Utah: unpublished report prepared by the Utah Geological Survey for the Utah School and Institutional Trust Lands Administration, 22 p., 1 appendix.

Staargaard, C.F., 2009, Geology and exploration at the Crypto zinc-indium-copper-molybdenum skarn deposit, Fish Springs mining district, Juab County, Utah, *in* Tripp, B.T., Krahulec, K., and Jordan, J.L., editors, Geology and geologic resources and issues of western Utah: Utah Geological Association Publication 38, CD, p. 139-151.

Solomon, B.J., 1993, Quaternary geologic maps of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah: Utah Geological Survey Open-File Report 296, 48 p. pamphlet, scale 1:24,000.

Stokes, W.L., 1963, Geologic map of Utah—northwest quarter: Salt Lake City, Utah State Land Board, scale 1:250,000.

Stokes, W.L., 1988, Geology of Utah: Utah Geological and Mineral Survey Miscellaneous Publication S, 317 p.

Thorman, C.H., Ketner, K.B., Brooks, W.E., Snee, L.W., and Zimmerman, R.A., 1991, Late Mesozoic-Cenozoic tectonics in northeastern Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, Geology and ore deposits of the Great Basin: Geological Society of Nevada, Symposium Proceedings, p. 25-45.

Tripp, B.T., 2005, High-calcium limestone resources of Utah: Utah Geological Survey Special Study 116, variously paginated, 7 appendices.

Tripp, B.T., Kirschbaum, M.J., Vanden Berg, M.D., Rupke, A.L., Gwynn, J.W., Boden, T., and Blackett, R.E., 2006, Chemical analyses of selected limestone, silica, and dolomite samples collected in northwest Utah, *in* Harty, K.M., and Tabet, D.E., editors, Geology of northwest Utah: Utah Geological Association Publication 34, CD-ROM, papers individually paginated, 16 p., 6 appendices.

Turk, L.J., 1973, Hydrogeology of the Bonneville Salt Flats, Utah: Utah Geological and Mineral Survey Water-Resources Bulletin 19, 81 p., 1 plate.

U.S. Steel, 1950, Preliminary report—Cricket lime and dolomite company property, Millard County, Utah: unpublished company report, 4 p.

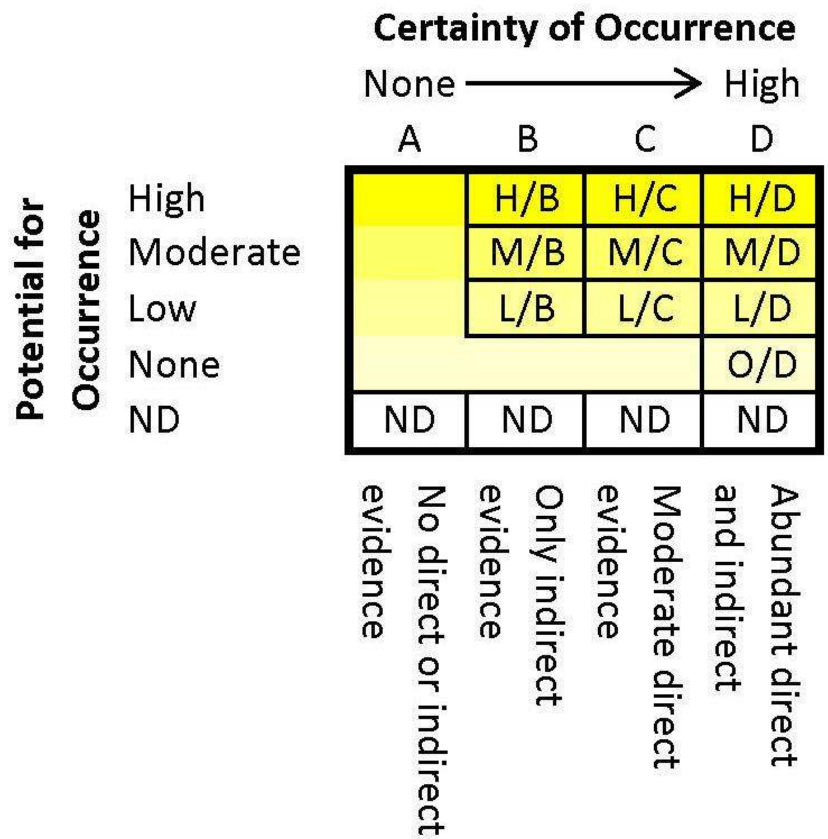
U.S. Steel, 1957, Evaluation of open hearth limestone deposits—central Utah and eastern Nevada: unpublished company report prepared by the Raw Material Exploration Division, 60 p.

Van Sant, J.N., 1964, Refractory clay deposits of Utah: U.S. Bureau of Mines Information Circular 8213, 176 p.

Willett, J.C., 2017, Stone (crushed), *in* U.S. Geological Survey, mineral commodity summaries: Online, https://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/mcs-2017-stonc.pdf, accessed April 2017.

Williams, J.S., 1958, Geologic atlas of Utah—Cache County: Utah Geological and Mineralogical Survey Bulletin 64, 104 p.

APPENDIX A. BLM MINERAL OCCURRENCE POTENTIAL AND UGS DEVELOPMENT POTENTIAL CLASSIFICATION SYSTEMS (from BLM Manual 3031)



BLM Potential for Occurrence Rating System

H: The geologic environment, the inferred geologic process, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, and the known mines or deposits indicate high potential for accumulation of mineral resources. The known mines and deposits do not have to be within the area that is being classified, but must be within the same type of geologic environment.

M: The geologic environment, the inferred geologic process, the reported mineral occurrences or valid geochemical/geophysical anomaly indicates moderate potential for accumulation of mineral resources.

L: The geologic environment and the inferred geologic process indicate low potential for accumulation of mineral resources.

O: The geologic environment, the inferred geologic process, and the lack of mineral occurrences do not indicate potential for accumulation of mineral resources.

ND: Mineral potential is not determined due to the lack of useful data. This notation does not require a level of certainty qualifier.

BLM Certainty of Occurrence Rating System

A: The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.

B: The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C: The available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources.

D: The available data provide abundant direct evidence and indirect evidence to support or refute the possible existence of mineral resources.

NONE: No data exist to prove or disprove the existence of economic mineral resources. (Note: the determination of "no potential (O)" for specific commodities implies O/D.)

UGS Development Potential Rating System

High (H): The geologic environment, the inferred geologic process, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, the known mines or deposits, and market factors indicate high potential for development of mineral resources. The known mines and deposits do not have to be within the area that is being classified, but must be within the same type of geologic environment.

Moderate (M): The geologic environment, the inferred geologic process, the reported mineral occurrences or valid geochemical/geophysical anomaly, and market factors indicate moderate potential for development of mineral resources.

Low (L): The geologic environment, the inferred geologic process, and market factors indicate low potential for accumulation of mineral resources.

None (O): The geologic environment, the inferred geologic process, the lack of mineral occurrences, and lack of positive market factors do not indicate potential for development of mineral resources.

Not Determined (ND): Mineral development potential is not determined due to the lack of useful data.

Although the development potential ratings are made on the basis of reasonable market assumptions at the time of their formulation or in the reasonable foreseeable short term, none of the above development potential ratings are given a level of certainty qualifier because future development potential is subject to too much market uncertainty beyond a few years' time frame from the date of prediction.